United States Department of the Interior

U. S. GEOLOGICAL SURVEY

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MEMORANDUM

To: Devin Galloway, WSFT-West Groundwater Specialist, Sacramento, CA

From: Keith J. Halford, C. Amanda Garcia, and Steve Reiner, Hydrologists, Nevada WSC, USGS

Subject: AQUIFER TEST—Analysis of *ER-20-4 main*, single-well aquifer test of volcanic rocks, Pahute Mesa, Nevada National Security Site

A single-well aquifer test was conducted by Navarro-Intera, LLC (N-I) at Pahute Mesa on the Nevada National Security Site (NNSS) in southern Nevada (Figure 1). Transmissivity of rhyolitic lava-flow aquifers within the Calico Hills zeolitic composite unit and Crater Flat confining unit were estimated (Table 1). Well ER-20-4 main was pumped intermittently between August 27, 2011 and September 21, 2011. Transmissivity estimated from the well *ER-20-4 main* aquifer test can be used to constrain estimates of radionuclide transport through volcanic rocks beneath Pahute Mesa, NNSS.

Site and Geology

The aquifer test occurred beneath Pahute Mesa in the northwest corner of NNSS where transport of radionuclides is a concern (Laczniak and others, 1996). The well monitored during single-well aquifer testing at Pahute Mesa is completed in Tertiary volcanic rocks. The volcanic rocks of Pahute Mesa are dominated by lavas and tuffs of rhyolitic composition (Laczniak and others, 1996). Geologic structures at Pahute Mesa include normal faults with surface exposure and buried structural zones and caldera margins (Figure 2). Major water-producing hydrostratigraphic units are the Tiva Canyon aquifer (TCA) and Topopah Spring aquifer (TSA), with some production from lava-flow aquifers in the Calico Hills zeolitic composite unit (CHZCM). Well ER 20-4 is located north of the Bench and east of the Boxcar fault (Figure 1). ER-20-4 penetrates about 1,500 ft of unsaturated rock, and 1,500 ft of saturated rock where it produces water from lava-flow aquifers within the CHZCM.

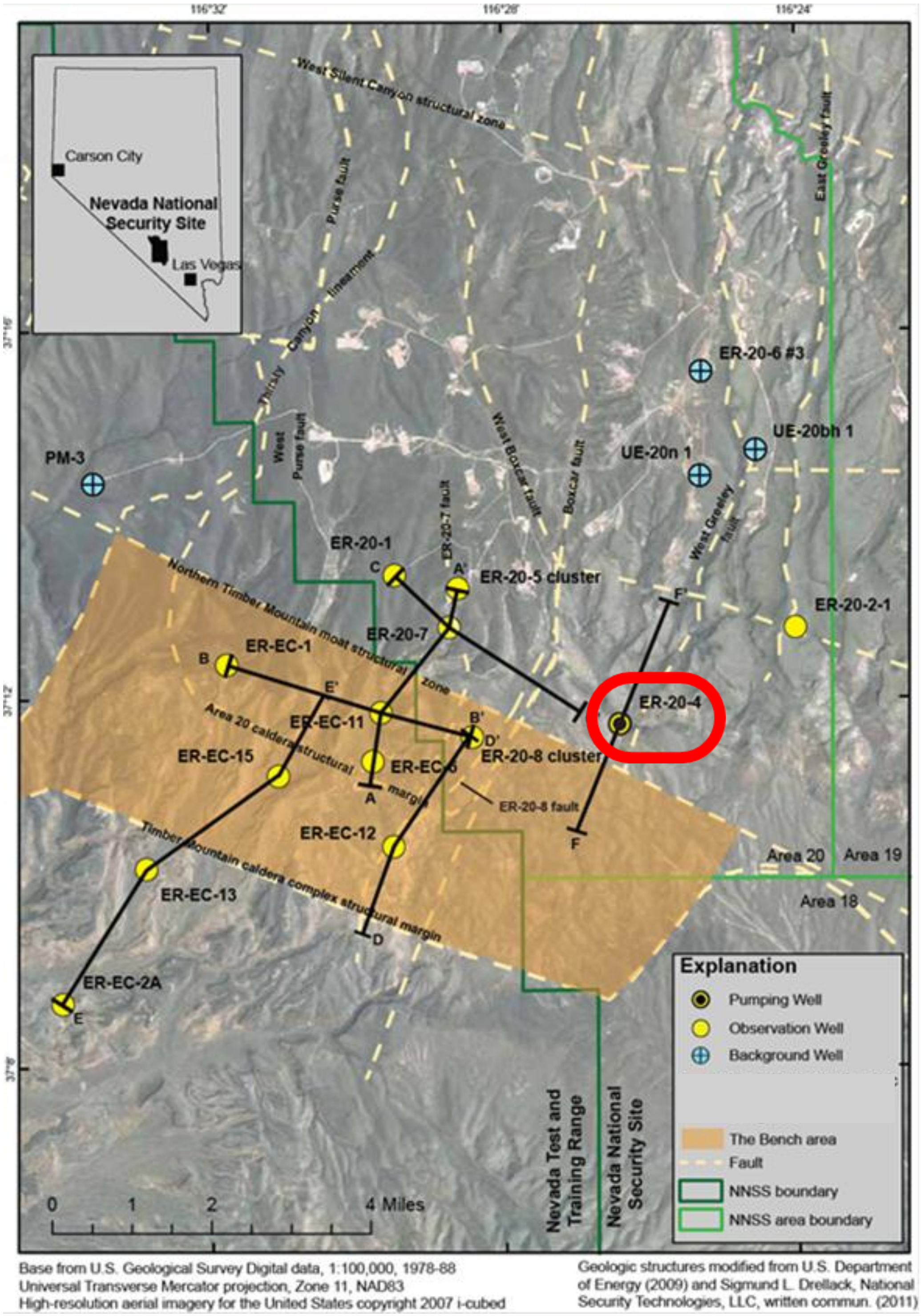

Figure 1.—Well construction, lithology, and location of well ER-20-4, Pahute Mesa, Nevada National Security Site and vicinity.

Table 1.—Well location and construction data for analyzed wells in ER-20-4 cluster, Pahute Mesa, Nevada National Security Site.

[Latitude and longitude are in degrees, minutes, and seconds and referenced to North American Datum of 1983 (NAD 83); ft amsl, feet above North American Vertical Datum of 1988 (NAVD 88); ft bgs, feet below ground surface.]

Map Identifier	SITE IDENTIFIER	Latitude	Longitude	Ground surface elevation, ft amsl	Depth to Static Water Level, ft bgs	Diameter Screen, in inches	Top Screen, ft bgs	Bottom Screen, ft bgs
ER-20-4 main	371143116262503	N37°11'43"	W116°26'25"	5,736	1,521	6 5/8	2,479	3,002
ER-20-4 deep	371143116262503	N37°11'43"	W116°26'25"	5,736	1,521	2 7/8	2,485	3,002

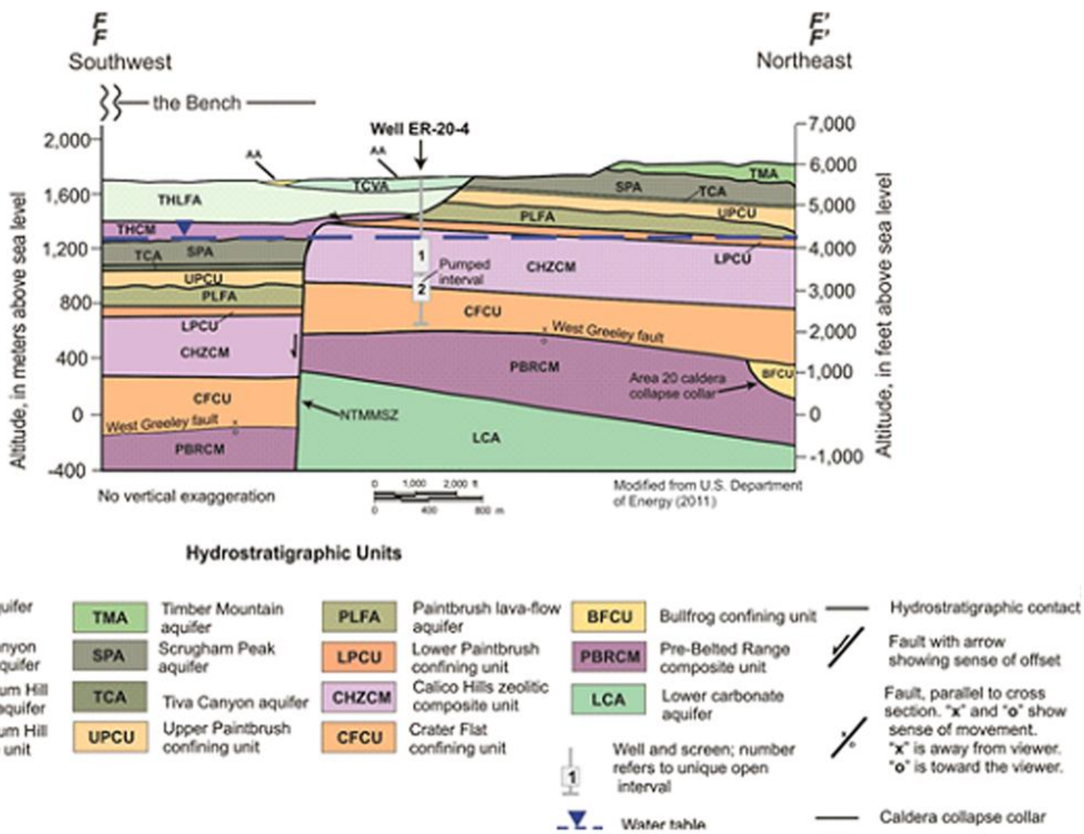

Figure 2.— Hydrostratigraphic section F-F' (includes well ER-20-4), Pahute Mesa, Nevada National Security Site.

The lithologies of major water-producing hydrostratigraphic units in the aquifer-test area are rhyolitic lava flows and welded ash-flow tuffs. These aquifers comprise rhyolitic lava flows with some intervals of vitrophyre, pumiceous lava, and flow breccias (U.S. Department of Energy, 2011). The TCA and TSA are welded-tuff aquifers. The ash-flow tuffs in these aquifers are partially to densely welded, with some nonwelded layers and local zeolitization. The CHZCM, and Crater Flat confining unit (CFCU) are composite units of rhyolitic lava-flow aquifers and nonwelded tuff confining units with local to common zeolitization (Laczniak and others, 1996, p.11; U.S. Department of Energy, 1997). The CFCU also contains welded-tuff aquifers.

Pumping

The open interval of ER-20-4 main is coincident with the open interval of well ER-20-4 deep and produces water from the CHZCM and CFCU (Figure 2, Appendix A). The constant-rate test lasted about 194 hours and was conducted from 9/13/2011 13:40 to 9/21/2011 15:25. Discharge during the constant-rate test averaged 283 gal/min with a total groundwater withdrawal of about 3.3 million gallons. Total withdrawal during the period of well development and testing was about 5.4 million gallons (Figure 3).

Water-level changes measured in ER-20-4 deep in response to pumping of well ER-20-4 main were simulated with a simplified pumping schedule. More than 16,000 pumping-rate measurements were made between August 25, 2011 and September 24, 2011 (Figure 3). These many measurements were reduced to less than 300 step changes during the well development and testing periods and were limited to 20 step changes during the constant-rate testing period (Figure 3).

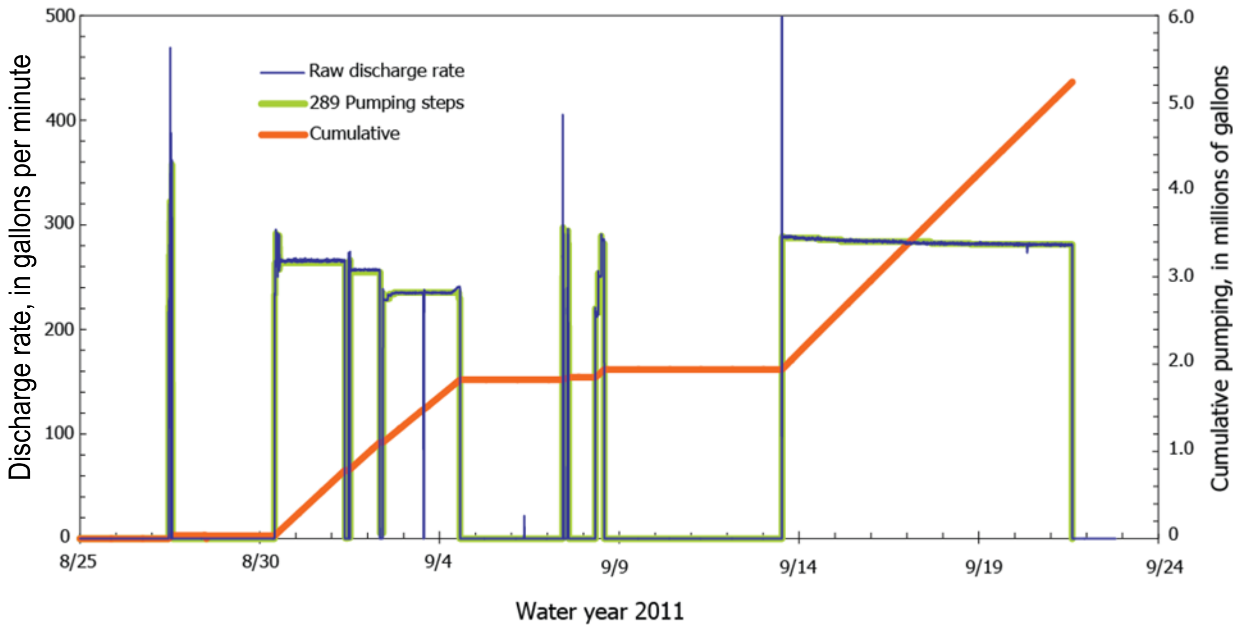

Figure 3.—Pumping from ER-20-4 during well development and aquifer testing, August-September, 2011.

Water Levels and Drawdowns

Drawdown estimates in well ER-20-4 deep (Figure 4), which is coincident with the pumping interval, are uncertain because of thermal expansion of the water column and changes in well-entry losses. Temperature increased 1 °C during the first day of pumping and less than 0.5 °C during the remaining 7 days of pumping well ER-20-4 main. Discharge exponentially declined during the constant-rate test from 288 to 280 gal/min between 9/13/11 12:40 and 9/21/11 13:20. Drawdowns were corrected for thermal expansion of the water column and changes in well-entry losses prior to estimating transmissivity.

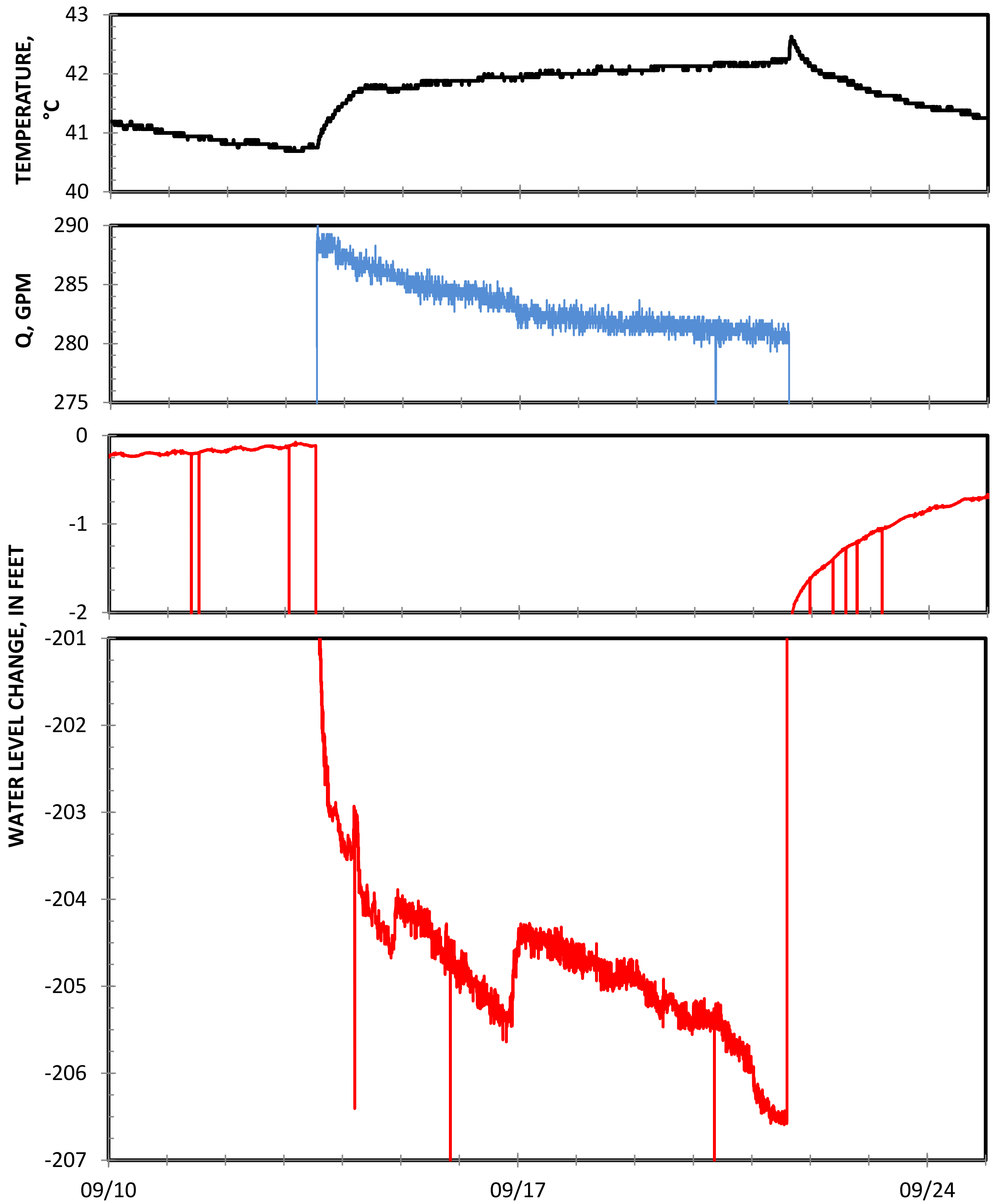

Figure 4.—Temperature, discharge rate, and water-level changes in well *ER-20-4 main* between September 10, 2011 and September 25, 2011.

Thermal expansion of the water column in well ER-20-4 deep caused water levels to rise less than 1 ft during the aquifer test. Temperatures that were measured in well ER-20-4 shallow were used because the temperature sensor failed in well ER-20-4 deep. Temperature changes near the static water level in wells ER-20-4 shallow and ER-20-4 deep should be similar because both wells are adjacent to the pumping well. Thermal expansion was the product of the thermal expansion coefficient of water (0.00034 °C/ft) and the difference in depths between the transducer and the center of the screened interval (1,200 ft). The entire column was assumed to heat uniformly because of the complex heating and cooling patterns that were induced by the pumping schedule (Figure 3).

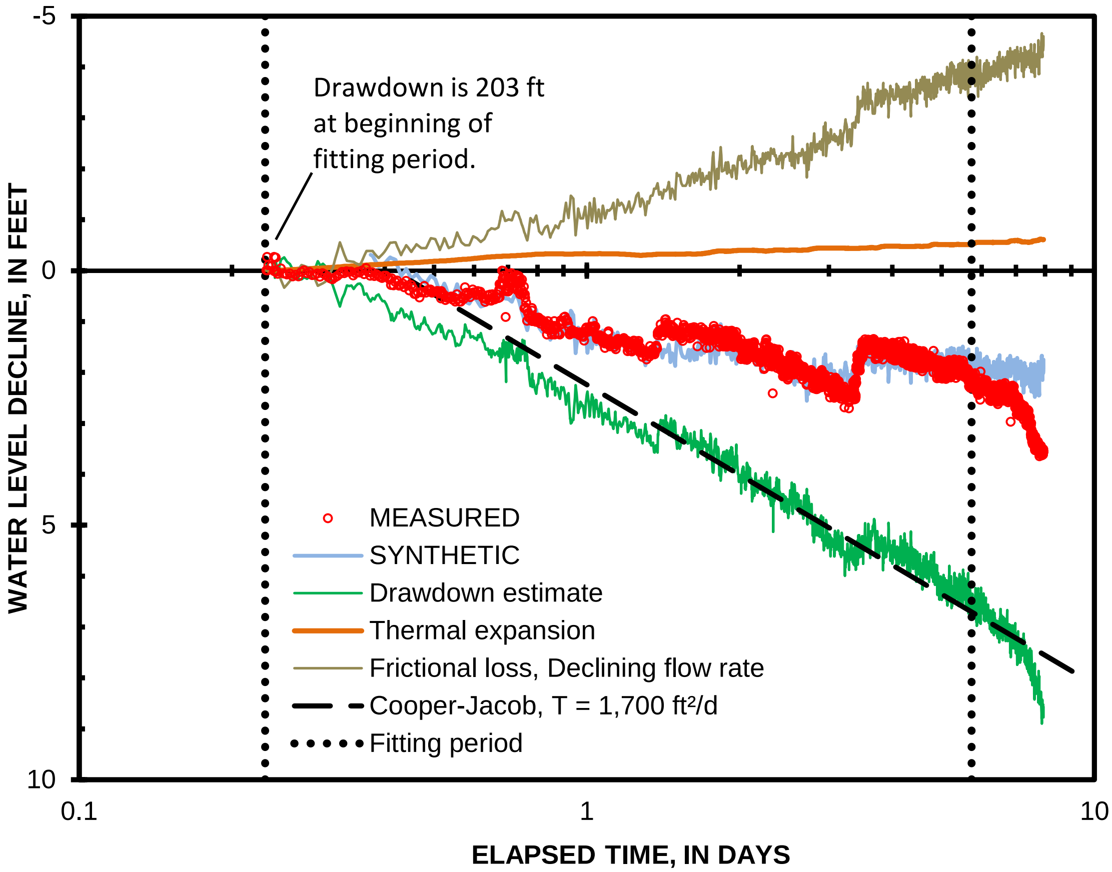

Figure 5.—Measured water level, synthetic water level, estimated drawdown, thermal changes, and change in well-entry losses in well *ER-20-4 deep* during the constant-rate aquifer test of *ER-20-4 main*.

About 80 percent of the water-level decline in well ER-20-4 deep during the constant-rate test could be interpreted as well-entry losses (Figure 4). Pumping water levels were sensitive to slight changes in discharge rates, where a 5 gal/min decrease caused water levels to rise 3 ft. Water levels rose more than 4 ft during the constant-rate test as discharge declined from 288 to 280 gal/min (Figure 5). Well-entry losses more likely were caused by more permeable intervals within the CHZCM and CFCU not being adjacent to the well screen of ER-20-4. Temperature changes with depth and limited flow measurements highlighted permeable intervals at 800 ft above and 100 ft below the well screen of ER-20-4 main (U.S. Department of Energy, 2011).

Analysis

A transmissivity of 1,700 ft^2/d was estimated for geohydrologic units that were penetrated by the ER-20-4 borehole. This value was estimated using a Cooper-Jacob single-well aquifer test analysis of drawdown (after about 5 hours of the constant-rate test) in ER-20-4 deep from the water-level model. Transmissivity would have been overestimated by more than a factor of two if drawdowns had not been corrected for thermal expansion of the water column and well-entry losses.

The fit between measured and synthetic water levels was poor during the last few days of the constant-rate test because additional drawdown likely resulted from vertical offset of the relatively thin permeable intervals (Figure 5). Vertical offset of more than 200 ft was possible along the West Greeley Fault, which lies less than 2,000 ft east of the ER-20-4 wells (Figure 1).

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Appendix A. Construction diagram well cluster ER-20-4

As-built diagram of the well completion for well cluster ER-20-4 which includes the wells *ER-20-4 main, ER-20-4 deep,* and *ER-20-4 shallow* (U.S. Department of Energy, 2011).